Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claim 1 (currently amended): A method for use with a crystal growing apparatus for optimizing a cooling rate of a monocrystalline ingot grown according to the a Czochralski process, said crystal growing apparatus having a heated crucible containing a semiconductor melt from which the ingot is grown, said ingot being grown on a seed crystal pulled from the melt, said crystal growing apparatus further having a receiving chamber into which the ingot is pulled, said ingot being pulled along a generally longitudinal path toward the receiving chamber, said method comprising:

determining a first temperature of the ingot when the ingot is at a first position along the path;

determining a second temperature of the ingot when the ingot is at a second position along the path, said first and second positions being separated by a distance D along the path;

determining a cooling rate of the ingot as a function of a difference between the first temperature and the second temperature relative to an amount of time for pulling the ingot the distance D;

generating a signal representative of an error between a target cooling rate of the ingot and the determined cooling rate of the ingot; and

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adjusting one or more post-growth processing parameters as a function of the error

signal thereby to control the cooling rate of the ingot.

Claim 2 (original): The method of claim 1, wherein determining the first temperature

includes measuring the first temperature of the ingot at a location along the length of the

ingot when the ingot is at the first position and determining the second temperature

includes measuring the second temperature of the ingot at the same location along the

length of the ingot when the ingot is at the second position.

Claim 3 (original): The method of claim 1 further comprising defining the target cooling

rate from historical processing data stored in a memory.

Claim 4 (original): The method of claim 1 further comprising defining a temperature

model representative of an estimated temperature profile along the length of the ingot

based on a sensed temperature when the ingot is initially pulled from the melt, and

wherein determining the first temperature includes estimating the first temperature of the

ingot at the location along the length of the ingot when the ingot is at the first position

along the path from the temperature model, and wherein determining the second

temperature includes measuring the second temperature of the ingot surface at the same

location along the length of the ingot when the ingot is at the second position after the

ingot is pulled the distance D along the path toward the receiving chamber.

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Claim 5 (original): The method of claim 1, wherein determining the cooling rate includes calculating a cooling rate C_R by the following:

$$C_R = (T_1 - T_2)/t$$

where T_1 is the first temperature, T_2 is the second temperature, and t is the amount of time required for the ingot to be pulled the distance D.

Claim 6 (original): The method of claim 1, wherein the ingot is pulled along the path toward the receiving chamber at a pull rate, and wherein adjusting the post growth processing parameter includes:

determining a pull rate set point as a function of the error signal; and

adjusting the pull rate according to the pull rate set point to control to cooling rate of the ingot.

Claim 7 (original): The method of claim 1, wherein the crystal growing apparatus has a heater positioned above the melt for heating the ingot as it is pulled along the path into the receiving chamber, and wherein adjusting the post growth processing parameter includes:

determining a heater power set point as a function of the error signal; and

adjusting power supplied to the heater according to the heater power set point to control the cooling rate of the ingot.

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Claim 8 (original): The method of claim 1, wherein adjusting the post growth processing parameter includes adjusting at least one of the following to control the cooling rate of the ingot: an argon gas flow rate; furnace pressure; heater power; and pull rate.

Claim 9 (currently amended): A method for use with a crystal growing apparatus for optimizing a cooling rate of a monocrystalline ingot grown according to the a Czochralski process, said crystal growing apparatus having a heated crucible containing a semiconductor melt from which the ingot is grown, said ingot being grown on a seed crystal pulled from the melt, said crystal growing apparatus further having a receiving chamber into which the ingot is pulled, said ingot being pulled along a generally longitudinal path toward the receiving chamber, said method comprising:

measuring a temperature of the ingot at a location along the length of the ingot at a position along the path;

generating a signal representative of an error between a target temperature of the ingot when it is at the position along the path and the measured temperature of the ingot; and

adjusting one or more post growth processing parameters as a function of the error signal thereby to control to cooling rate of the ingot.

Claim 10 (original): The method of claim 9 further comprising defining the target temperature from historical processing data stored in a memory, and wherein the target temperature is dependent on the position along the path at which temperature is being measured

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Claim 11 (original): The method of claim 9, wherein adjusting the post growth

processing parameter includes adjusting at least one of the following to control the

cooling rate of the ingot: an argon gas flow rate; furnace pressure; heater power; and pull

rate.

Claim 12 (currently amended): An apparatus for use with a crystal growing apparatus for

optimizing a cooling rate of a monocrystalline ingot grown according to ~~the~~ a

Czochralski process, said crystal growing apparatus having a heated crucible containing a

semiconductor melt from which the ingot is grown, said ingot being grown on a seed

crystal pulled from the melt, said crystal growing apparatus further having a receiving

chamber into which the ingot is pulled, said ingot being pulled along a generally

longitudinal path toward the receiving chamber, said method comprising:

a first temperature sensor positioned along the path of the ingot for measuring a

first temperature of the ingot surface at a location along the length of the ingot when the

ingot is at a first position along the path;

a second temperature sensor positioned along the path of the ingot for measuring

a second temperature of the ingot surface at the same location along the length of the

ingot when the ingot is at a second position along the path, said first and second positions

being separated by a distance D;

a controller for generating an error signal representative of an error between a

target cooling rate of the ingot and a calculated cooling rate of the ingot, said calculated

cooling rate being calculated as a function of a difference between the first temperature

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and the second temperature relative to an amount of time for pulling the ingot the

distance D; and

a processing component responsive to the error signal for adjusting a processing

parameter set point as a function of the error signal to control the cooling rate of the

ingot.

Claim 13 (original): The apparatus of claim 12, wherein the processing component

generates a pull rate set point as a function of the error signal, and wherein a puller motor

is responsive to the pull rate set point generated by the processing component to adjust

the pull rate of the ingot thereby controlling the cooling rate of the ingot.

Claim 14 (original): The apparatus of claim 12, wherein the crystal growing apparatus

has a heater positioned above the melt for heating the ingot as it is pulled along the path

into the receiving chamber, and wherein the processing component generates a heater

power set point for the power supplied to the heater as a function of the error signal, and

wherein a power supply is responsive to the heater power set point generated by the

processing component for adjusting the power supplied to the heater thereby controlling

the cooling rate of the ingot.

Claim 15 (original): The apparatus of claim 12, wherein the processing component

generates a flow rate set point for an argon gas being introduced into the crystal growing

apparatus as a function of the error signal, and wherein an argon flow component is

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responsive to the flow rate set point generated by the processing component to adjust the flow rate of the argon gas thereby controlling the cooling rate of the ingot.

Claim 16 (original): The apparatus of claim 12, wherein the temperature sensor is configured to sense a temperature of an ingot surface, and generates a temperature signal representative of the sensed temperature.

Claim 17 (original): The apparatus of claim 12 further including a central processing unit for processing historical processing data to identify the target cooling rate and a memory for storing the target cooling rate.

Claim 18 (original):. The apparatus of claim 12, wherein an operator uses a computer linked to a memory to define the target cooling rate.

Claim 19 (currently amended): An apparatus for use with a crystal growing apparatus for optimizing a cooling rate of a monocrystalline ingot grown according to ~~the~~ a Czochralski process, said crystal growing apparatus having a heated crucible containing a semiconductor melt from which the ingot is grown, said ingot being grown on a seed crystal pulled from the melt, said crystal growing apparatus further having a receiving chamber into which the ingot is pulled, said ingot being pulled along a generally longitudinal path toward the receiving chamber, said method comprising:

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a temperature sensor positioned along the path of the ingot for measuring a

temperature of the ingot surface at a location along the length of the ingot when the ingot

is at a position along the path;

a controller for generating an error signal representative of an error between a

target temperature of the ingot when it is at the position along the path and the measured

temperature of the ingot; and

a processing component responsive to error signal for adjusting a processing

parameter set point as a function of the error signal to control the cooling rate of the

ingot.

Claim 20 (original): The apparatus of claim 19, wherein the target temperature is defined

from historical processing data stored in a memory, and wherein the target temperature is

dependent on the position along the path at which temperature is being measured

Claim 21 (original): The apparatus of claim 19, wherein the processing component

generates a pull rate set point as a function of the error signal, and wherein a puller motor

is responsive to the pull rate set point generated by the processing component to adjust

the pull rate of the ingot thereby controlling the cooling rate of the ingot.

Claim 22 (original): The apparatus of claim 19, wherein the crystal growing apparatus

has a heater positioned above the melt for heating the ingot as it is pulled along the path

into the receiving chamber, and wherein the processing component generates a heater

power set point for the power supplied to the heater as a function of the error signal, and

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wherein a power supply is responsive to the heater power set point generated by the processing component for adjusting the power supplied to the heater thereby controlling the cooling rate of the ingot.

Claim 23 (original): The apparatus of claim 19, wherein the processing component generates a flow rate set point for an argon gas being introduced into the crystal growing apparatus as a function of the error signal, and wherein an argon flow component is responsive to the flow rate set point generated by the processing component to adjust the flow rate of the argon gas thereby controlling the cooling rate of the ingot.

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